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Research Note 85-73

EXPERIMENTAL EVALUATION OF THE SUPERDART PROJECTILE LOCATION SYSTEM

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The purpose of this report is to report the test results of the Superdart Projectile Location System, an electronic target system capable of registering the locations of both hits and complete misses on field fire targets. Tests were performed using Australian soldiers firing at Superdart stationary and moving targets. Other tests were performed, using the equipment in automatic, night, suppressive, protective mask, and assault firing. The targetry equipment has value for training with precise hit-and-miss feedback, determining what and how to train, and for test and evaluation of weapons, ammunition, and equipment.

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INTRODUCTION

The Superdart Projectile Location System is a live-fire target device capable of detecting and locating the position of a passing supersonic projectile and displaying its precise location, whether target hit or complete miss. At the invitation of the Australian Government, representatives of the U.S. Army, U.S. Marine Corps and the Army Research Institute recently had the opportunity to examine and test Superdart in detail. The purpose of this report is to document this testing and the findings and to indicate some very interesting training and testing implications of this revolutionary new technological breakthrough.

Ever since riflery began a major goal of marksmanship trainers has been to find means to provide feedback to the shooter about location of his various shot attempts. Without that detailed feedback learning is seriously hampered.

The known distance (KD) range has been one of the best and most popular feedback methods used. Persons protected beneath the target line score and spot shots with markers visible back on the firing line. While the feedback is quite precise, the procedure is very labor intensive and the firer knows the distance to his one and only target. Attempts of thirty years ago to provide a transition to more combat-like field firing required cable-erected pop-up targets that couldn't be scored except by inspection, or required safety mounds of earth protecting persons who hoisted silhouette targets upon command and then gave a signal of a hit if detected.

In 1954, as a part of the research that led to the TRAINFIRE rifle training curriculum, a killable target was invented that changed field firing. The shock of a bullet impact on the man-shaped target momentarily opened an electrical switch which, in turn, caused the target to fall automatically. The target could be placed at any range and electrically raised and lowered. Because of the hit sensing, the shooter could see at a glance if he had fired successfully. Once the student had become capable in fundamental shooting skills, learned with high quality feedback at 25 meter or KD ranges, the killable target was then used to aid in transition to the essential skills of combat shooting against fleeting, surprise targets appearing at unknown ranges.

This impact sensing target technology has been in use for more than 25 years with little basic change. Unfortunately, the U.S. Army rifle marksmanship training program has drifted slowly away from feedback-laden 25 meter and KD firing into greater and greater dependence upon such killable target devices, not as transitional tools but rather as the prime device for <u>most</u> marksmanship training. The serious flaw in this shift is that the beginning shooter frequently completely misses the target and can't tell where the bullet went, so correction is difficult or perhaps impossible. The good shooter hits somewhere on a 19-inch wide by 30 to 40 inch high target surface but doesn't know where and so often he too profits little from practice.

Small wonder then that many manufacturers have tried for years to develop a means to register the position, whether hit or miss, of a projectile as it passes the plane of a target. Until almost 1980 no attempt had been fully satisfactory. Superdart is a recent, successful breakthrough which is the most exciting marksmanship target device since the invention of the killable target. Combining the projectile location system and the killable target offers great promise for a quantum jump in marksmanship training.

METHOD

With the assistance of the Australian Embassy in Washington, D.C., plans were developed for a research trip to Albury, New South Wales, Australia, the site of the manufacturing facilities of Australasian Training Aids Pty. Ltd. Arrangements were made to permit use of Australian soldiers as test subjects in experiments examining stationary and moving target firing on Superdart target equipment.

Test Subjects

The Infantry Centre at Singleton, New South Wales, Australia, provided the soldiers to aid the research team in evaluating the use of Superdart. All were Infantry Privates at or near the end of their Advanced Infantry Training (AIT). They ranged in age from 17 to 25, with a median age of 19.2. Time in service spanned 4 to 27 months, with a median of 5.9 months. All had a large amount of military small arms experience, mostly with the primary service rifle (7.62 Fabrique National L1A1, referred to as the SLR) but all had prior experience with the M16A1 rifle (employed by the Australian Army in a carbine role and used for all testing reported here). Sixty-nine percent had much prior civilian experience with large or small calibre rifles or shotguns and only 16 percent had no civilian weapons experience.

For the Superdart evaluation two groups of test subjects were needed, an experimental group to be given Superdart feedback and a control group receiving only hit-miss information. Forty-eight men were pretested at Singleton Infantry Centre on an M16A1 record fire scenario using targets at 75, 175 and 300 meters. Of this total, 32 men were picked and assigned in matched pairs to the two groups (of 16 each) based upon total hits registered on this test scenario. Unfortunately, two conditions during the pre-test limited the effectiveness of the subject assignment procedure. Malfunctioning targets in certain lanes of the Singleton rifle range caused elimination of 16 men from consideration because no clear estimate was possible of their skill. High and gusty wind also seriously depressed hits at greater range and may have unevenly affected different firing orders throughout the day.

The Superdart equipment was available for testing only in Australia, hence the use of Australian troops. In a comparison of these men with American soldiers, whom they replaced in testing, several differences should be noted. The Australian soldiers were somewhat older and were much more experienced in civilian and military small arms than is typical of U.S. Infantrymen in AIT training. Through two weeks of daily contact it also became clear that the Australian soldiers made available for this test were of higher average intelligence than could be expected of typical U.S. Infantry AIT soldiers.

The Superdart Projectile Location System

The detection portion of the Superdart Projectile Location System is shown in simplified form in Figure 1. Depicted are a target (A) mounted on a killable target holder (B) with the detector bar assembly (C) attached on top. As the bullet heads towards the target it passes over or near the position locating sensors, (F, G and H) spaced along the detector bar and then either misses or hits the target (in this case a hit at D). The supersonic shock wave propagates from the bullet path (E) down to the three sensors (F, G and H). A local microprocessor contained in the detector bar precisely measures the differential times required for the sound to reach the detectors. From this information actual location of the bullet can be calculated. The forward sensor (I) allows for the measurement of bullet velocity.

The horizontal and vertical error signals are conveyed back to the firing point and displayed on a video display unit (VDU). Target operation, quality of hit, point scoring and display formats (e.g., printout) can be arranged according to test or training needs by simple computer programs. During the test, software was available for programmed zeroing of the rifle, successive ring hit scoring, horizontal and vertical error, radial miss distance and information about each shot of automatic fire in the sequence fired.

Figure 2 shows one of the VDU formats used for a ten shot sequence. Note that shot sequence numbers were displayed, ricochets were detected and hits were scored 5, 4 or 3 depending upon electronically determined scoring "rings". A companion printer gave: hit or miss, point score, horizontal and vertical error distance and radial miss distance. We took advantage of these capabilities in our various data collection efforts.

Plan of the Research

The major testing examined Superdart as an aid to learning to hit stationary and moving targets. For both of these tests a standard experimental vs. control group design was employed. The two groups were given a pre-test, then accorded differential treatment (Superdart feedback during training vs. hit-miss only feedback). Finally, a post-test was used to examine the lasting effects of the treatment.

Stationary Target Firing. A 300 meter target was used as the only target for this portion of the test. It would have been desirable to test multiple targets at various ranges but the company test range did not accommodate more than one target at a time. During the pre-test the two groups fired 10 shots at this target which was set to fall when hit. Then the experimental group soldiers were allowed to view the VDU after each of their next 20 shots so that they could see exact hit or miss location. They were not given any instruction about wind, holdoff, correction of aim-point, etc., but were told the object was to do the best they could with the VDU cues. The controls, meanwhile, fired their 20 bullets with hit-miss feedback but no VDU screen feedback. Both groups then took a 10 trial post-test without VDU feedback.

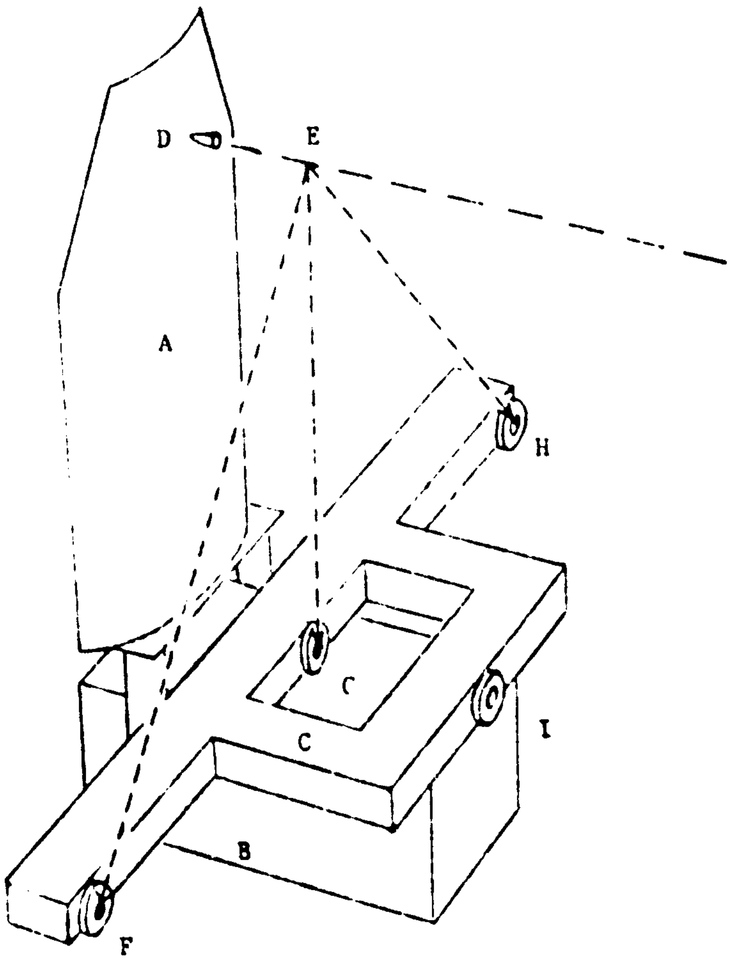
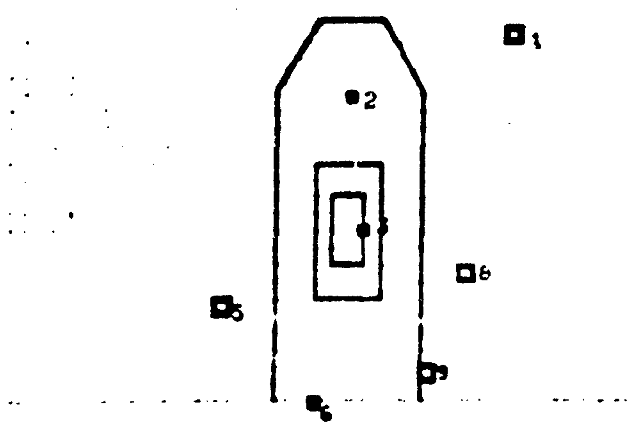


Figure 1. Superdart Projectile Location System showing the target (A), target mechanism (B), and the detector T-bar (C). The detectors (F, G, H) provide information to allow precise location of the bullet, whether hit or miss. The forward detector (I) aids in measuring bullet velocity. More detail is presented in the body of the report.



SHOT	SCORE
1	0
2	3
3	5
4	1-RIC. H.
5	0
6	3
7	0-RIC. H.
8	0
9	0
10	
TOTAL	12

Figure 2. One video display unit (VDU) format used for Superdart performance feedback, shot location and sequence are pictured; closed square for hit, open square for miss. Also shown is a 5, 4, 3 scoring format for hits, with a 1 awarded for a ricochet hit.

Moving Target Firing. The same two groups of soldiers also participated in the moving target test. A 20 trial pre-test with no VDU feedback was given, 10 shots fired from 50 meters and 10 from 137 meters distance from a laterally moving target travelling at an average speed of 5.1 miles per hour. The direction of movement (to the left or right) was unpredictable but half travelled in each direction.

The two groups then were given lead rule instructions for less than and greater than 100 meters and were taken to another firing area where they were given 20 shots at a slower moving target (3.1 MPH) located at a distance of 100 meters. For the first ten shots targets moved left to right; for the remainder right to left. The experimental group shooters were given VDU feedback to see exactly where their shots hit or missed. The controls saw only low shots or whether the target fell if hit. Additional practice (30 shots) was then given at a range of 137 meters, using the faster moving target. The target moved left to right for the first ten, right to left for the second ten and half and half for the final ten shots. The same VDU feedback for the experimentals and lack of VDU feedback for the controls was employed.

Both groups were finally given a repeat of the pre-test as a post-test with no VDU feedback given to either group.

RESULTS AND DISCUSSION

Stationary Target Firing

The results of the 300 meter stationary target firing are shown in Table 1. The table gives hits, scores, and radial miss distance data. Any hit on the target surface counted one point (with 10 hits possible). See Figure 2 for details of the "score" measure. Scores were the total of hits in the smallest rectangle (each scored 5), hits in the "ring" formed by the larger rectangle (scored 4) or elsewhere on the target surface (scored 3). The highest possible "score" was ten 5s or 50 points. Radial miss distance was the miss distance from target center in centimeters, taking both horizontal and vertical error into account. The best possible radial miss distance would thus be zero.

Unfortunately, the two groups were not equal on the pre-test. The control group averaged 7.5 hits while the experimental group hit 6.8. This was before the use of Superdart so the groups should have been equal. Also considering that these were the first ten shots fired at the 300 meter target, 7.5 and 6.8 are very high hit rates that have relatively little room for improvement. U.S. soldiers in training usually hit no more than 3 of 10 targets at 300 meters.

The most sensitive measure of hit performance available in this experiment was radial miss distance--the miss distance in centimeters from the center of the target. With the introduction of the 20 trial precise feedback provided by the Superdart VDU the experimental group's performance improved (i.e.,

TABLE 1

Stationary Target Hits*, Score* and Radial Miss Distance* for the Experimental vs. the Control Groups for the Pre-test, Practice and Post-test Trials

		Pre-test No VDU Feedback	1st Practice With VDU Feedback	2d Practice With VDU Feedback	Post-test No VDU Feedback
Experimental Subjects	Hits	6.8	8.1	8.0	8.2
	Score	23.1	29.9	29.8	30.1
	Radial Miss Dist.	27.4	21.2	21.1	22.1
			Without VDU Feedback		
Control Subjects	Hits	7.5	7.4	7.6	8.0
	Score	25.5	25.4	25.7	28.3
	Radial Miss Dist.	27.2	28.3	26.2	23.6

*Any hit on the target surface counted one point (with 10 hits possible). See Figure 2 for details of the "score" measure. Scores were the total of hits in the smallest rectangle (each scored 5), hits in the "ring" formed by the larger rectangle (scored 4) or elsewhere on the target surface (scored 3). The highest possible "score" was ten 5s or 50 points. Radial miss distance was the miss distance from target center in centimeters, taking both horizontal and vertical error into account. The best possible radial miss distance would thus be zero.

the miss distance decreased) while the control group's did not. The analysis of variance of this interaction taking into account experimental groups and trials was significant ($F = 3.35$, $df = 2, 60$, $p < .05$).

The 300 meter target was situated on a hill side at the far side of a ravine. A burlap screen was placed behind the target to prevent the firer from seeing dirt puffs from misses landing behind. Low shots impacted into the hill, however, and so were visible. Therefore, in the 40 shots fired by the controls some miss feedback was often received to aid in correction. The controls could also aim at different points to explore for the best spot. In spite of these aids the overall hit performance of controls improved only 6.6 percent while experimentals improved 20.6 percent from pre to post-test.

The small size of the two groups (N = 16 each), the single target only, the high quality zero for each rifle, the cues available to the controls and the limited use of Superdart (only 20 shots with limited instruction) probably all combined to reduce the effect of the Superdart feedback potential. Even in this modest experiment the value as a training aid is clear and further testing involving more trials and more extensive training in how to use the feedback is indicated. This conclusion is further supported by additional data gathered later from the control group.

Upon completion of all of the firing required by the stationary and moving target tests the control group soldiers were brought back to the stationary target range for one additional test in which they too had a chance to utilize the Superdart feedback from the VDU. This testing occurred in mid-afternoon and typically there was by then a brisk cross wind blowing at 10 or more miles per hour. The testing began with 10 shots with no VDU feedback. The 16 men averaged 6.7 hits. The wind appeared to be responsible for several of the misses. There were then two practice 10-trial blocks with VDU feedback. The men averaged 7.9 on the first and 9.0 on the second (for a 33.5 percent increase in hits). In the post-test they averaged 8.3 hits. The radial miss distance measures for the four trial blocks were 27.3, 23.1, 18.2 and 21.7 centimeters for pre-test, first practice, second practice and post-test respectively. The pre-test to second VDU practice comparison and the pre-test vs. post-test improvements were statistically significant ($t = 3.52$, $df = 15$, $p < .01$ and $t = 2.25$, $df = 15$, $p < .05$ respectively). So both the experimental and control subject groups showed reliable improvements when given the feedback -- and that was so even though initial performance level was already quite high.

Moving Target Firing

All of the ten-trial averages for the pre-test, practice and post-test for moving target firing are shown in Table 2. This experiment occurred after the 300 meter firing so the participants were well practiced in firing. As before only one target could be used at a time which may partly account for the high hit rates. The skill observed was surprisingly high even on the pre-test. For the 50 meter and 100 meter target firing the lead rule was

TABLE 2

Moving Target Hits*, Score* and Radial Miss Distance* for the Experimental vs. Control Group for the Pre-test, Practice and Post-test Trials

		Pre-Test		100 Meter Practice		137 Meter Practice			Post-Test	
		50M	137M	1st 10	2d 10	1st 10	2d 10	3d 10	50M	137M
	Hits	8.0	6.3	8.7	8.4	8.3	8.3	7.4	8.6	7.6
Experi- mental	Score	28.9	21.4	31.9	31.4	28.9	29.6	25.9	31.7	25.8
	Radial Miss. Dist.	19.7	30.4	19.3	18.6	21.7	20.3	23.9	19.7	23.6
	Hits	8.5	5.9	8.9	8.6	6.6	7.6	6.8	8.9	7.2
Control	Score	32.1	20.3	33.6	31.2	22.9	27.1	23.7	34.4	25.8
	Radial Miss Dist.	16.8	32.1	18.1	19.9	29.1	24.4	26.4	15.0	24.6

*Any hit on the target surface counted one point (with 10 hits possible). See Figure 2 for details of the "score" measure. Scores were the total of hits in the smallest rectangle (each scored 5), hits in the "ring" formed by the larger rectangle (scored 4) or elsewhere on the target surface (scored 3). The highest possible "score" was ten 5s or 50 points. Radial miss distance was the miss distance from target center in centimeters, taking both horizontal and vertical error into account. The best possible radial miss distance would thus be zero.

to bisect the front sight post with the target's leading edge. Overall, almost everyone hit almost every 50 meter moving target. No Superdart practice was ever given at that range so it didn't feature in the experiment. At 100 meters again nearly all targets were hit so even though Superdart feedback was given to the experimental group there was little room for improvement. The 137 meter moving target required a somewhat greater lead (front sight post in front of the target and tangent to its leading edge). There was a tendency for the experimental group to improve more (as a result of Superdart feedback) from pre-test to the first practice period (31.7 percent) compared with the controls who improved 11.9 percent. This improvement differential failed to reach statistical significance however ($F = 3.28$, $df = 1, 30$, $p < .10$) Overall, all men fired ninety shots at single targets with known distance and the specified sighting rule for 100 meters and less or for greater than 100 meters. The groups both showed improvements probably from the tracking practice they received. With more targets moving faster and presented at different ranges the Superdart capability to show exact hit and miss location would very likely be of benefit but this necessarily simplified experiment with its high initial hit rates failed to show the expected benefit.

Adequacy and Accuracy of the Superdart System

Before any testing began all soldiers zeroed their rifles using a Superdart box target (a more accurate version of the device than that shown in Figure 1). It was located at a range of about 33 meters from the firing point. The associated computer program indicated on the VDU shot locations, 3-shot group mean point of impact, whether the shot group was "tight" enough to permit sight changes and the number of sight clicks necessary to correct any vertical or horizontal errors. This system worked extremely well and the quality of zero obtained was confirmed by the later 300 meter and moving target shooting. The system could be used at any chosen range. For example, in the U.S. Army Marksmanship Program zeroing could be carried out at actual 250 meter range, perhaps with the equipment even compensating for any wind influence that might be present.

During target change a caliper jig is used to precisely locate the point of target center above the projectile location system detection transducers so that the target or aiming point can be accurately positioned in its holder. Using this jig to set the target center accurately and to center a witness panel paper overlay, we fired on the box target and then measured the distance of each shot from target center and compared it with the calculated bullet position printed by the Superdart equipment. For the box target the median error between the calculated and measured positions was 1.0 millimeters (mm) left or right with the worst error being only 1.3 mm. On the vertical axis the median error was 1.1 mm, with the worst discrepancy being 2.5 mm. In short, the system is capable of locating shots in two-dimensional space with accuracy far in excess of the needs of the Army training program. The manufacturer states than an even more accurate version of the box target it available for use in international competitive shooting events but we did not test it.

A similar accuracy check was made of the T-bar detection system pictured in Figure 1. With this less precise system the median horizontal error was still only 1.7 mm and the worst error 4 mm. As with the box target the accuracy is less in the vertical axis. The median error was 9.8 mm, with the worst error being 14 mm. This comparative test was performed on shots which had travelled 300 meters to the target. This Superdart equipment was thus able to tell the firer 300 meters away where his bullets had landed with a worst error of only about a half-inch. That accuracy would be more than adequate for even the most stringent military training requirement for field firing (e.g., Sniper instruction). In all of our testing the projectile location system capability also appeared to be stable and reliable.

Automatic Fire

The effectiveness of the U.S. Army's current automatic fire training is questionable at best. Part of the reason may be the inability of current target equipment and procedures to provide sufficient (or any) information concerning quality of hit, location of misses, and sequence of hits within a particular burst of fire.

A very functional feature of Superdart is the ability to record the hit or miss location of every shot in sequence during a burst of full-automatic fire. We examined this automatic fire recording capability by firing various burst lengths using several different rifle holding techniques (e.g., sling, bipod). The targets in Figure 3 reveal the type and quality of feedback provided by the Superdart equipment.

While our pilot tests provided insufficient data to determine the training effectiveness of the equipment in an automatic fire role, projectile location technology shows obvious promise for the development of training procedures, automatic fire training, and weapons testing.

Suppressive Fire

The Infantryman in combat is seldom presented with a well defined, clearly visible target. He is often required to fire at known or suspected enemy locations using battlefield clues (e.g., covered or concealed areas, smoke, dust, movement) or he is directed to provide suppressive fire in a particular location. Current target equipment is unable to provide information concerning the effectiveness of suppressive fire.

According to the manufacturer, the Superdart transducers are capable of detecting and locating passing bullets out to a radius of five meters. This capacity would permit, for the first time, feedback about effectiveness of suppressive fire. All of the uses of Superdart described so far involve a visible target positioned over the detector bar. However, the target is unnecessary for projectile location. For suppressive fire, detector arrays could be hidden (with no visible target) behind rocks or bushes, along tree lines, etc. Soldiers could then be evaluated to see if they fired at those appropriate "suspected enemy locations" or successfully suppressed their assigned firing sector.

The Superdart equipment we evaluated is designed for use on training ranges where lanes will be in close proximity. Therefore, the sensitivity of the sensing devices has been electronically limited to avoid detecting bullets fired on the adjoining lane. Even in its current configuration the equipment provides good feedback about suppressive fire as shown in Figure 4. Indicated are the pattern and maximum horizontal and vertical detection ranges of the current device. Misses out to 1 1/2 to 2 meters were detected and located.

Currently, most tactical live fire exercises are evaluated by the volume of ammunition that is expended. Target equipment with this or expanded capability

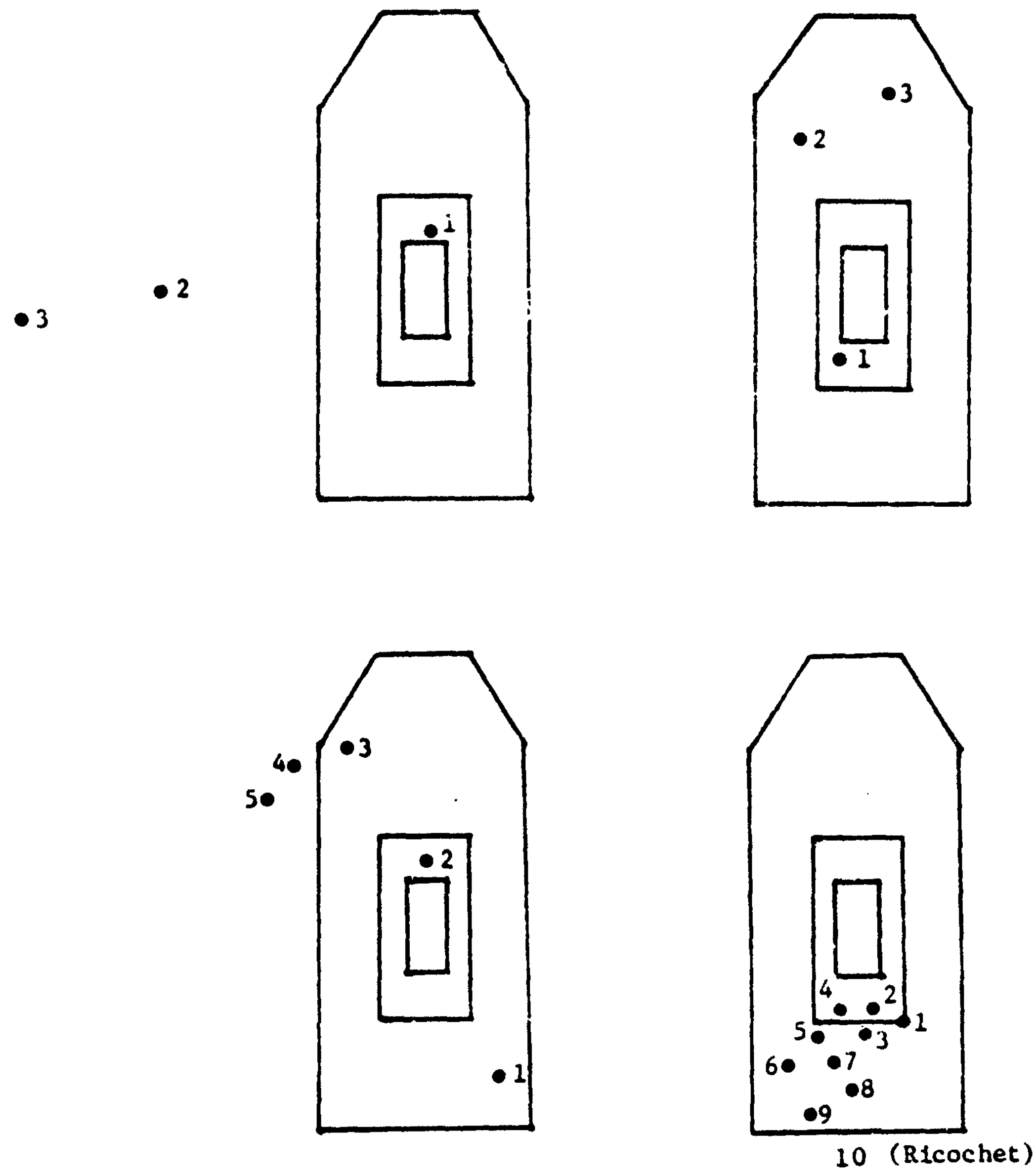


Figure 3. Examples of Superdart Projectile Location System records of full-automatic fire. The top targets were engaged from a distance of 100 meters and the bottom targets were engaged from a distance of 50 meters. The shot patterns reflect differences among various firing positions.

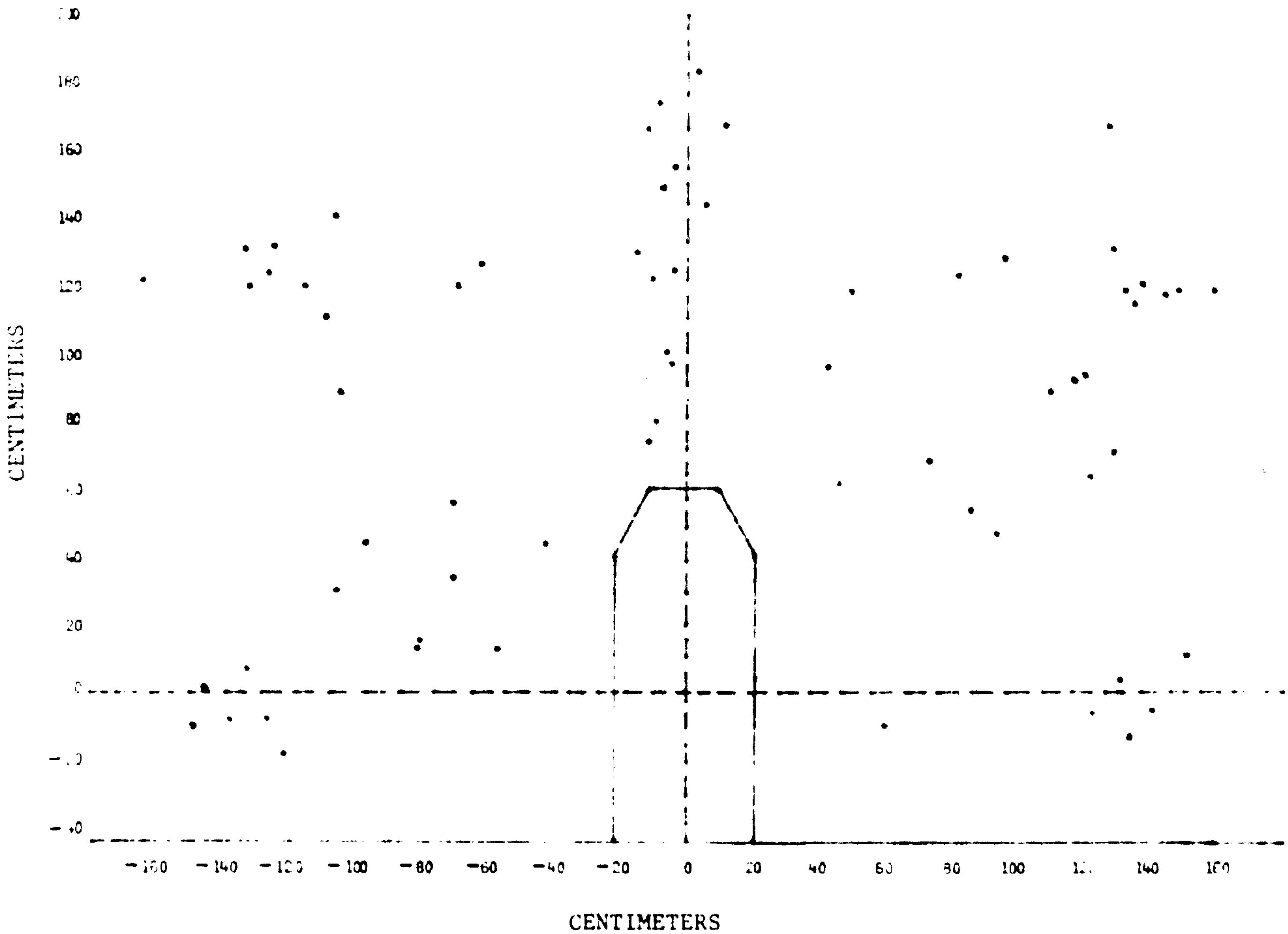


Figure 4. The Superdart Projectile Location System records misses as well as target hits. These firings were conducted to determine the maximum detection range in its current configuration. Bullet hits are shown in Centimeters from target center. Without electronic limits the equipment should be capable of registering misses out to a radius of five meters.

offers potential for better measuring the total useful combat power generated by a unit, thereby contributing to more realistic and meaningful training.

Night Firing

The ability to engage targets successfully at night or in poor illumination is a training problem for all armies. In low light conditions it is often necessary to look over the top of rather than through the rear sight. While ultra precise bullet location is probably not necessary for learning to control crude night pointing techniques, feedback must be available for performance to improve.

We had opportunity to conduct only limited night fire testing of Superdart. The equipment appeared to have considerable potential for adjusting the low visibility, crude aiming of the rifle. As with suppressive fire training, however, Superdart with a broader radius of detection would probably be most successful for night fire training. This is particularly true in the vertical axis because there is a tendency to shoot high at night (due to looking over the rear sight).

Sufficient firings were not conducted to determine training effectiveness; however, the equipment offers promise to update training procedures and doctrine for night firing. In addition to providing precise feedback results and eliminating many of the typical safety problems associated with night firing, this equipment may allow each soldier to develop night firing techniques that work best for him.

Protective Mask Firing

The Army fully recognizes the requirement to function on Nuclear, Biological or Chemical (NBC) Battlefields. Firing the service rifle while wearing the NBC protective mask is a critical task that must be included in rifle training.

In order to see through the M16A1 sights while wearing the protective mask it is necessary to cant the rifle by as much as 45 degrees from the vertical. The sights are about 2.6 inches above the bore, with the rear sight higher than the front sight. As with all rifles this causes a parallax problem which is compounded with cant. Beyond 42 meters the M16A1 bullet will strike the target in error somewhat in the direction of the cant. Also the bullet will strike low because with greater and greater cant the sight line more and more approximates the bore line. Recognizing these problems of cant, we took advantage of the Superdart location capability to conduct some tests of firing with the M17A1 protective mask.

Several firings were conducted to determine the relationship among weapon cant, aiming point, and bullet impact on a 300 meter silhouette target. A significant observation was that variability among individuals (e.g., in aim point placement and in cant) may require training programs which provide for shooting practice at various range targets while

providing precise feedback on bullet hit/miss locations. It appears, though, that with limited exposure to precise feedback a good marksman using the M16A1 rifle can hit all personnel size targets at ranges out to 300 meters while wearing the protective mask. The Superdart equipment has the potential of making significant improvements in the capability of the American soldier to effectively engage targets in an NBC environment.

Assault Firing

Soldiers conducting an assault against an enemy position are highly vulnerable, but adequate training in appropriate assault fire techniques could greatly influence their success. This most critical phase of attack receives little U.S. Army training emphasis, due partly to serious safety considerations but also to inability to measure firing performance. We used Superdart to run limited experiments on effectiveness of various assault firing techniques.

The equipment in its tested configuration is unsuitable for assault fire training. It probably needs a five meter shot registration capability because wild shots currently often are out of detection range. The Superdart target did allow some judgments to be made about relative effectiveness of various techniques. As currently designed Superdart could at least be utilized as an aid in development of assault fire doctrine and training procedures and, with modification, may be very beneficial for training effective assault firing procedures.

CONCLUSIONS

The purpose of this report has been to assess the capability and suitability of the Superdart Projectile Location System. It appears to have considerable promise in three areas: (1) assisting the student and the teacher by providing the feedback necessary for learning the results of each shot attempt, (2) developing information about what to train and how to accomplish that training and, (3) serving as a test instrument for evaluating performance of weapons, ammunition and equipment.

Training

Information has been presented in this report that shooting performances were improved by providing detailed hit and miss feedback. This occurred in spite of excellent initial skill levels of the Australian soldiers who participated in the study. Any estimate of the value of Superdart type equipment for training U.S. Army soldiers must consider that the average U.S. soldier (at any time in his Army Career) can hit no more than 30% of the comparable stationary or moving targets used in the pretests of our experiments, while the Australian soldiers hit 70 to 80% prior to training.

Other factors probably served to reduce the differential skill improvements shown by the experimental and control groups. One factor is that Superdart equipment was used to zero the rifles of both groups of subjects,

resulting in a more precise zero than that normally obtained. Therefore, fewer targets were missed - reducing the value of detailed miss feedback. An additional consideration is the limitation of only one target at a time during testing. The simple one-target task, repeated several times, also allowed the control subjects to find-the-mark, reducing the performance difference that would probably result from a more complex target scenario.

The Superdart Projectile Location System appears to have the potential of making significant improvements to marksmanship training of the American soldier, especially recognizing the current room for skill improvement. It can greatly enhance the following marksmanship training areas: stationary targets, moving targets, automatic fire, suppressive fire, night firing, protective mask firing, assault firing, and small unit (collective marksmanship) tactical firing exercises.

Additionally, the equipment offers great promise for teaching junior leaders and other marksmanship instructors. The overall quality of marksmanship within the Army would probably improve dramatically if selected leaders/instructors were trained with precision and immediate feedback provided for each round of ammunition fired.

There are many pros and cons to training on a known distance (KD) range and many pros and cons to training on a Trainfire pop-up target range. The Superdart Projectile Location System conveniently avoids most of the cons of both while incorporating the advantages of the KD range (primarily the precise location of each bullet fired) and the advantages of Trainfire (the surprise presentation of the fleeting, short exposure, combat like targets from unknown locations and unknown ranges in a field environment). It also provides the capability to measure the effectiveness of suppressive fire and of automatic fire. It very likely would increase training gain per round of ammunition - hence potentially permitting ammunition savings for a given desired skill level.

Finding Out What to Train

The training developer could utilize this equipment as a valuable tool in finding out what and how to train. Limited experimentation with automatic, night, assault, and protective mask firing indicates that more valid doctrine and more effective training techniques could be developed with immediate and precise shot by shot feedback for all ranges, all targets, and all conditions.

Test and Measurement

The utility of projectile location equipment in a testing environment should be obvious. Realistic testing and evaluation of marksmanship equipment requires test subjects to fire at simulated combat targets. But, current target equipment is usually capable of providing only hit/miss results. The quality of hits and the proximity of misses (suppressive fire) are important data which would

be provided by projectile location equipment and could be major influences in the selection of weapons or equipment for the U.S. Army. Failure to register bullets that impact short of the target (and don't ricochet nearby) or to detect bullets farther away than the pickup radius are potential test and measurement drawbacks but the Superdart system is clearly a major advance.

Reliability

A brief look at Superdart on the factory test range will not provide assurance that the equipment will function in an all-weather field environment; however, our tests spanned three weeks of warm and cold temperatures and no malfunctions of the projectile location system portions of the equipment were ever noted.

RECOMMENDATIONS

The Superdart Projectile Location System has been demonstrated to have the potential for significant, perhaps dramatic improvements in marksmanship skill and knowledge acquisition. Currently the U.S. Army is planning replacement of much of the Trainfire equipment with a computer controlled system called IRETS (infantry Remoted Target System). IRETS permits many different forms of combat oriented scenario representations with both stationary and moving targets. Unfortunately it provides only hit/miss feedback (as did Trainfire). This type of feedback is suitable for much performance evaluation but it is severely limited in training value for fundamentals skill acquisition. Therefore, it is recommended that the U.S. Army acquire sufficient projectile locating equipment for in-depth testing with American soldiers. Ideally, testing the projectile locating technology as a companion to IRETS or as a substitute for portions of it should be pursued.